VIII. STRUCTURAL WALL CHANGE (STRUCTURAL BREADTH)

BACKGROUND:

The gymnasium and multipurpose room at Carderock Springs were designed as load bearing CMU walls with joists resting over top of the wall to carry the roof load. The rest of the building's typical construction is a steel frame. In the two areas where the typical steel frame meets these two rooms, there needs to be increased coordination to ensure joists can be set on time to go with the flow of the structural steel. This work requires two contractors to work in the same area, which is not ideal.

Figure 19 - Picture of Gymnasium

Figure 20 - Picture of Multipurpose Room

GOAL:

The goal of this analysis is to change the structure of these two areas to steel so that they can be erected independently of another contractor's work. This should increase the efficiency of the steel crew and allow the critical path to move faster, since a steel column and beams are faster to erect than building a load bearing masonry wall. In addition, there would be less constructability and coordination issues which would minimize potential risk.

RESEARCH STEPS:

To begin this analysis, a cost estimate will be done to estimate the cost of the original construction. This will be used later to compare costs to the steel structure. The next aspect will be the re-design of the two areas using structural steel. After the design is complete, estimates for the new cost and schedule will be made. These will then be used to compare to the original schedule which will be used as the baseline and the original estimated costs for the construction. Finally, advantages and disadvantages will be assessed for use in the final recommendation.

RESOURCES:

The primary resource used was the AISC Steel Construction manual. Other resources included online joist catalogs and the assistance of other students. RS means was used for cost estimates.

DESIGN:

The design was completed using Load and Resistance Factor Design (LRFD) method. The gravity design was the only design considered within the scope of this analysis. In general the design followed these steps:

1. Determine roof loads using drawings and ASCE 7-05.
2. Perform preliminary layout and spacing of columns and beams.
3. Determine loads to columns and beams using original roof and joist plan.
4. Size beams and columns.

To determine the sizes of beams and columns, a simplified method was used. Instead of designing each beam and column independently, the maximum load condition was found. This condition was then repeated at the regular intervals of the new design. These two spaces are rectangular and benefit from a simple repeating design. Masonry will still be used in these spaces as partitions to separate them either from the exterior or other interior spaces.

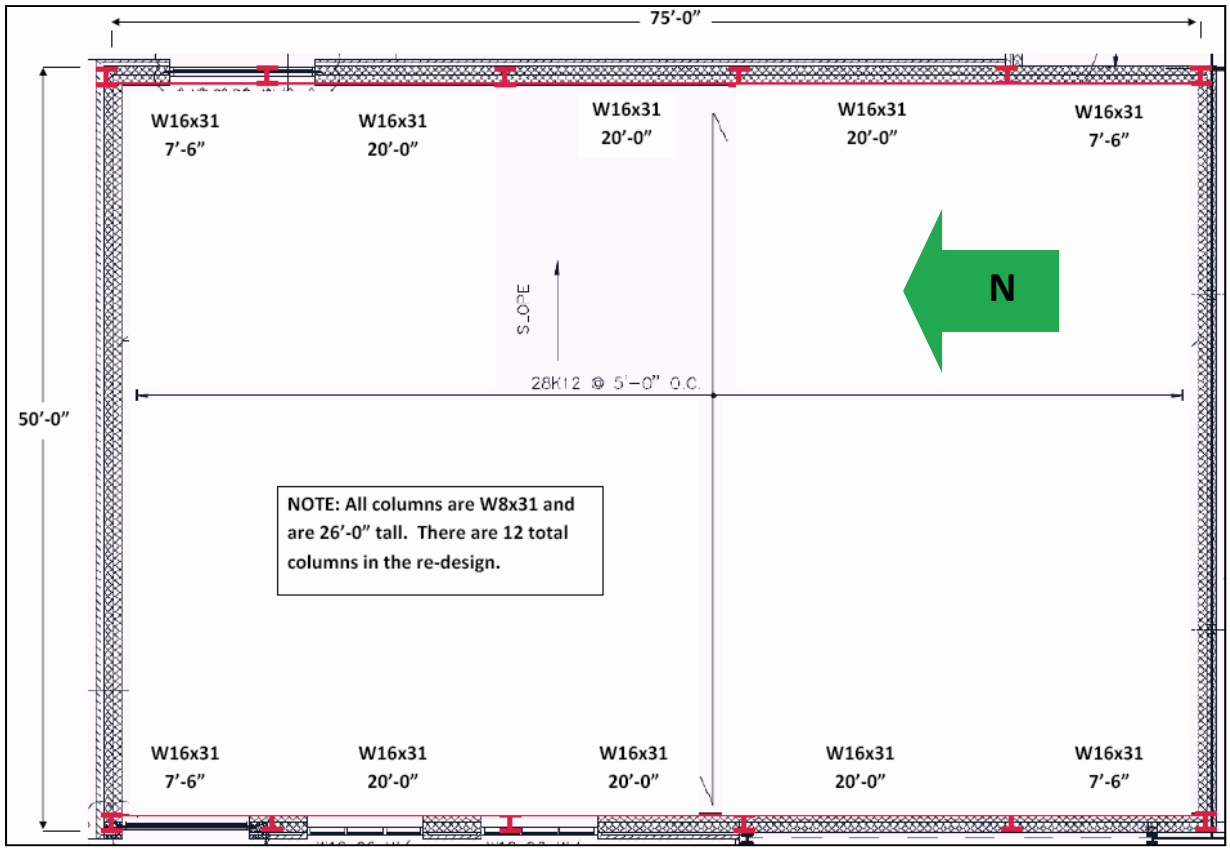

Figure 21 - New Gym Structural Design

The above figure represents the final design of the gymnasium space. Detailed hand calculations can be found in the attached appendix E. The gym is 75 by 50 feet and will utilize W16x31 beams and W8x31 columns with 50 KSI steel. The plan north and south walls are partially exposed to the exterior as well as the entire plan west wall. This type of partition will be a 12" thick CMU exterior wall. The remaining areas will be interior walls which will be 8" CMU with a painted final finish.

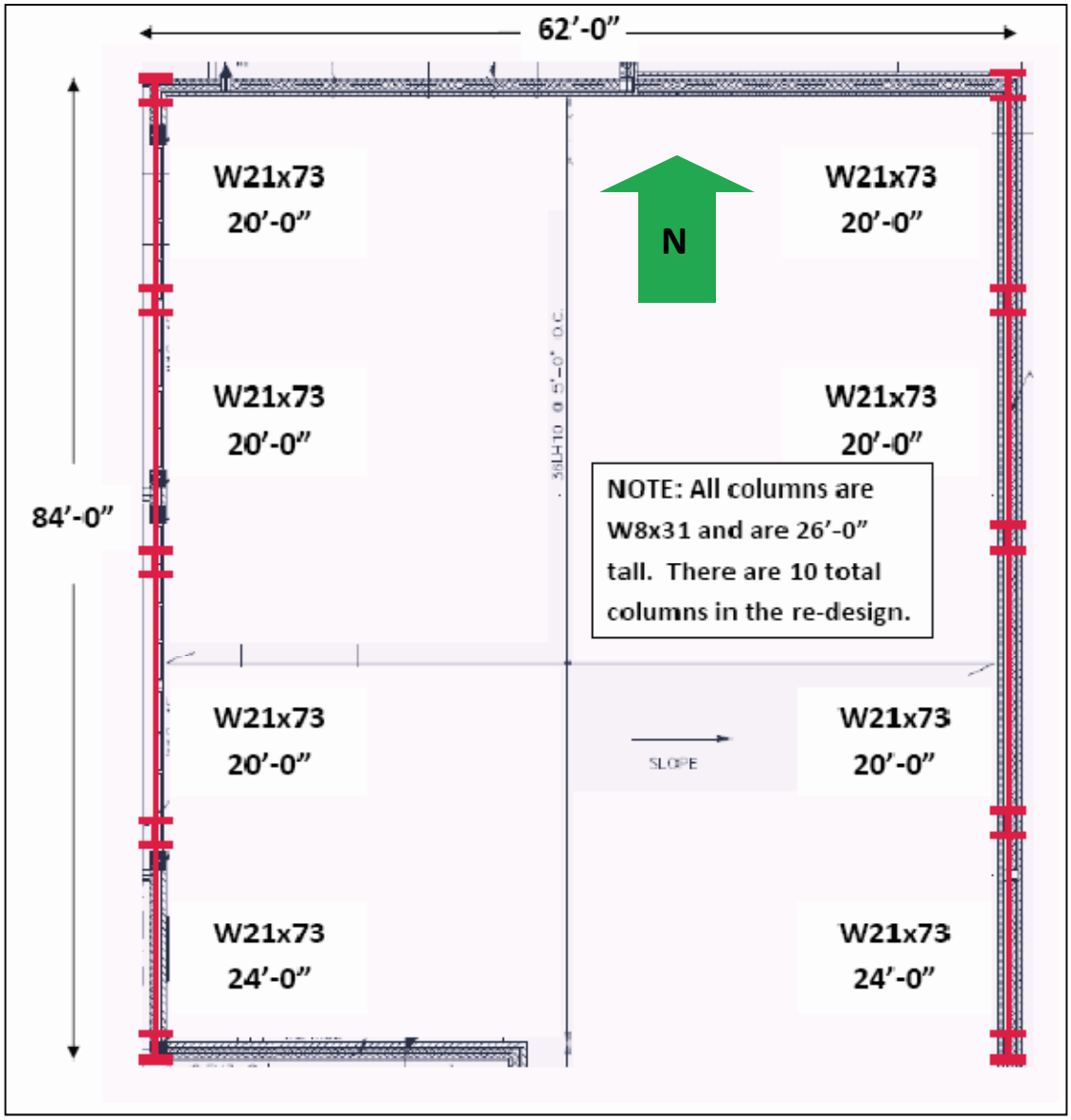

Figure 22 - New MPR Structural Design

The above figure represents the final design of the multipurpose room space (MPR). Detailed hand calculations can be found in the attached appendix ?. The MPR is 62 by 84 feet and will utilize W16x73 beams and W8x31 columns with 50 KSI steel. All of the walls with the exception of the plan east walls are interior. The interior walls will be 8" with a painted finish. The exterior walls will be 12" CMU with painted interior finish and a brick ledge on the outside façade.

CONSTRUCTABILITY & SCHEDULE:

The constructability and coordination of the original design was a very detailed scenario. The original construction called for steel joists to rest on a masonry load bearing CMU wall. This schedule calls for the steel erector and masonry company to work very closely together to coordinate placing the steel joists immediately after the masonry is complete and the grouted walls are cured. The construction schedule called for the joists to be placed upon completion of the walls. See the detail to the right for the specific connection requirements.

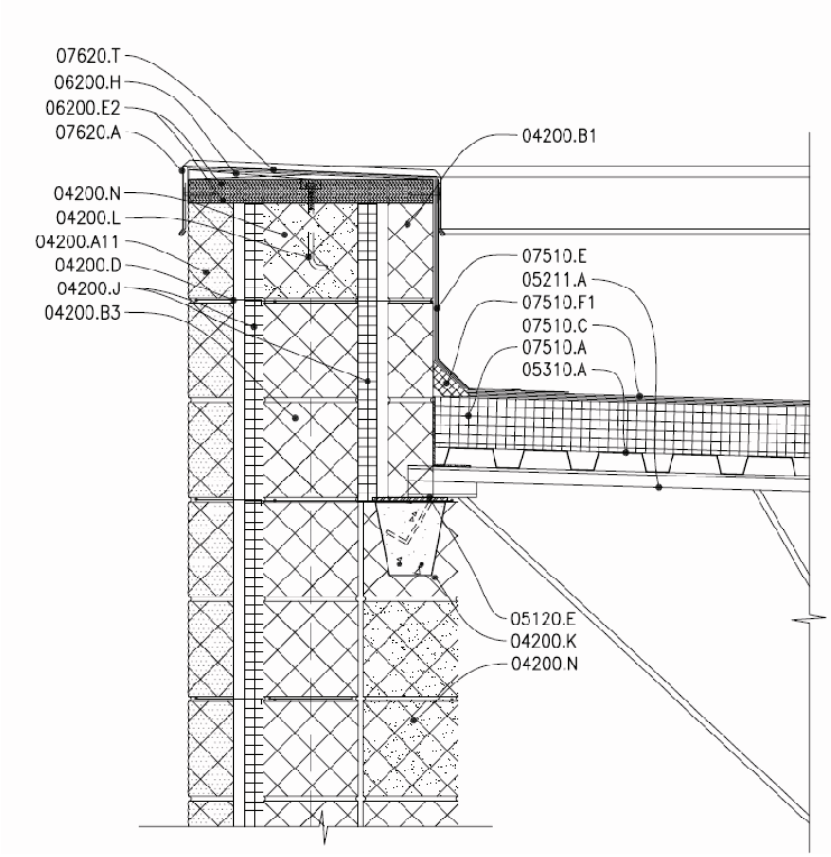

Figure 23 - Typical Masonry Bearing Wall Joist Bearing Detail

Issues can arise in multiple scenarios with the original design. One scenario is that the masonry is lagging while the steel erector stays on schedule. This would mean that the joists would be on site and ready to be erected but the masonry walls would not be ready. In this scenario the steel erector would be slowed down and a new plan would have to be developed to keep the steel erector's working. This would most likely cause conflict since contractors do not like to be slowed or delayed by another contractor. Most schedules and construction plans account for this and allow contractors to work in specific areas for specific durations. However in a scenario such as this, there is no choice but to have to closely coordinate the work.

All different combinations of the masonry lagging or the steel being ahead would cause a disruption to the original schedule. The only good scenario would be that the masonry crews are ahead of schedule.

With the steel structure, these problems would be eliminated. The steel contractor would be ahead of the masonry contractor (as is typical for a primarily steel superstructure) and would not have to worry about syncing their schedule with the mason's schedule. They could complete the work with a little more leeway and freedom. In this scenario, the mason crew would follow behind the steel erector and neither would affect each other's work.

Also in the steel scenario, time can be saved on the critical path. The original schedule calls for 20 days to complete the gym walls which are on the critical path (The multipurpose room is not on critical path). Steel can generally be erected faster than masons can build load bearing CMU walls. On this project, this is the case since only typical construction techniques. Using steel, the schedule is reduced by 12 days moving the finish date from July 7, 2010 to June 21, 2010. These calculations were performed using the following technique:

1. Use original schedule to determine steel erection rates of other similar portions of the project. Result = 45 pieces of steel (beams and columns) can be erected in 5 days.

2. Use proportions to estimate new steel duration.

    a. 45 pieces/5 days = # steel pieces in Gym or MPR/x days

3. Use original masonry duration for load bearing walls in both spaces to find difference.

4. Subtract durations to get new duration and find schedule savings.

Table 8 - Schedule Savings from Structure Change

Room	Original Duration	New Duration	Work Days Saved
Gym	20	8	**12**
MPR	10	6	**4**

Note: Only Gym on the Critical Path

Original Project Finish: July 7,2010
New Project Finish: June 21, 2010

COST

Building with masonry is a very labor intensive activity. The process of moving bricks, concrete masonry units, and mortar is very difficult and requires many men skilled and unskilled. Erecting steel requires less labor in comparison to masonry. The labor inputs of steel erection are the crane operators, riggers, and setters. Then after setting, a bolt up or

welding crew to finish the connections. The following tables show the differences in cost of the two systems.

Table 9 - Cost of Original Gym Structure

Gymnasium - Original Construction									
				Cost Per SF			Total Cost Per SF		
Wall Type	SF of Wall	CMU Size	Core Fill	Material	Installation	Total	Material	Installation	Total
Interior	3380	12x8x16	Grout	$4.70	$8.80	$13.50	$15,886	$29,744	$45,630
Exterior	3120	12x8x16	Grout	$4.70	$8.80	$13.50	$14,664	$27,456	$42,120
								Final Cost:	*$87,750*

Table 10 - Cost of Original Multipurpose Room Structure

Multipurpose Room - Original Construction									
				Cost Per SF			Total Cost Per SF		
Wall Type	SF of Wall	CMU Size	Core Fill	Material	Installation	Total	Material	Installation	Total
Interior	7592	12x8x16	Grout	$4.70	$8.80	$13.50	$35,682	$66,810	$102,492
Exterior	2184	12x8x16	Grout	$4.70	$8.80	$13.50	$10,265	$19,219	$29,484
								Final Cost:	*$131,976*

Table 11 - Cost of New Gym Structure

Gymnasium - Redesigned Structure									
				Cost Per SF			Total Cost Per SF		
Wall Type	SF of Wall	CMU Size	Core Fill	Material	Installation	Total	Material	Installation	Total
Interior	3380	8x8x16	Hollow	$2.55	$6.20	$8.75	$8,619	$20,956	$29,575
Exterior	3120	8x8x16	Grout	$3.05	$6.60	$9.65	$9,516	$20,592	$30,108
								Final Cost:	*$59,683*

Table 12 - Cost of New Multipurpose Room Structure

Multipurpose Room - Redesigned Structure									
				Cost Per SF			Total Cost Per SF		
Wall Type	SF of Wall	CMU Size	Core Fill	Material	Installation	Total	Material	Installation	Total
Interior	7592	8x8x16	Hollow	$2.55	$6.20	$8.75	$19,360	$47,070	$66,430
Exterior	2184	8x8x16	Grout	$3.05	$6.60	$9.65	$6,661	$14,414	$21,076
								Final Cost:	*$87,506*

Table 13 - Summary of Structural Change Costs

Structural Steel Cost for both Areas						
Member Size	**Area**	**Function**	**Linear Feet**	**Weight (ton)**	**Cost/Ton**	**Total Cost**
W16x31	Gym	Column	312	4.84	$2,819	$13,633
W8x31	Gym	Beam	150	2.33	$2,819	$6,554
W21x73	MPR	Column	168	6.13	$2,819	$17,286
W8x31	MPR	Beam	260	4.03	$2,819	$11,361
					Totals:	***$48,834***

The previous tables demonstrate the cost differences, especially in labor, for a reinforced CMU load bearing wall. These walls take considerably more time to build than a standard CMU partition with no load bearing ratings. It is seen that in both rooms, money is saved in both materials and labor to only construct standard partition and exterior walls for the spaces. The masonry costs were derived from RS Means Assemblies guide. The last table shows the costs for the additional steel. These costs were found from using the detailed takeoff of steel on the project to find the price per ton of steel with installation included.

Table 14 - Overall Cost Summary for Structural Change

	Original			Redesign					
				Masonry		Steel			
Room	Material	Labor	General Cond.	Material	Labor	Mat. + Install	General Cond.	Percent Difference	Total Savings
Gym	$30,550	$57,200	$52,860	$18,135	$41,548	$20,187	$21,144	50.28%	$39,596
MPR	$45,947	$86,029	xxxxx	$26,021	$61,485	$28,647	xxxxx	12.75%	$15,824
Totals	*$76,497*	*$143,229*	*$52,860*	*$44,156*	*$103,033*	*$48,834*	*$21,144*	*22.63%*	*$55,420*

Notes: Multipurpose room not on the Critical Path, therefore no G.C. savings
General Conditions derived from actual budget in General Conditions Estimate section of report

This last table shows the total dollar savings from the new system with general conditions included. Although, $55,420 is a small savings compared to the $21 million total cost of the project, it would still be appreciated by any owner. That dollar amount could relate to a pure cost savings or could allow for the owner to upgrade equipment or enhance the project with an add-alternate. One particular item on this project was an outdoor sustainable garden space with a small amphitheatre design that was selected to be constructed by the owner after the bid. A small savings such as this could help offset or completely pay for a space such as this.